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DATA SHEET

PCA16xx series
32 kHz watch circuits with EEPROM

Product specification
Supersedes data of 1997 Apr 21
File under Integrated Circuits, IC16

1997 Dec 12

Philips Semiconductors

PHILIPS

32 kHz watch circuits with EEPROM PCA16xx series

FEATURES

- 32 kHz oscillator, amplitude regulated with excellent frequency stability
- High immunity of the oscillator to leakage currents
- Time calibration electrically programmable and reprogrammable (via EEPROM)
- A quartz crystal is the only external component required
- Very low current consumption; typically 170 nA
- Detector for silver-oxide or lithium battery voltage levels
- Indication for battery end-of-life
- Stop function for accurate timing
- Power-on reset for fast testing
- Various test modes for testing the mechanical parts of the watch and the IC.

GENERAL DESCRIPTION

The PCA16xx series devices are CMOS integrated circuits specially suited for battery-operated, quartz-crystal-controlled wrist-watches, with bipolar stepping motors.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE(1)		
	NAME	DESCRIPTION	VERSION
PCA1601U/10	–	chip on foil	–
PCA1602T	PMFP8	plastic micro flat package; 8 leads (straight)	SOT144-1
PCA1603U/7	–	chip with bumps on tape	–
PCA1604U	–	chip in tray	–
PCA1604U/10	–	chip on foil	–
PCA1605U/7	–	chip with bumps on tape	–
PCA1606U/10	–	chip on foil	–
PCA1607U	–	chip in tray	–
PCA1608U	–	chip in tray	–
PCA1611U	–	chip in tray	–
PCA1621U/7	–	chip with bumps on tape	–
PCA1621U/10	–	chip on foil	–
PCA1622U	–	chip in tray	–
PCA1623U/7	–	chip with bumps on tape	–
PCA1624U	–	chip in tray	–
PCA1625U/7	–	chip with bumps on tape	–
PCA1626U	–	chip in tray	–
PCA1627U/7	–	chip with bumps on tape	–
PCA1628U	–	chip in tray	–
PCA1629U/7	–	chip with bumps on tape	–

Note

1. Figure 1 and Chapter “Package outline” show details of standard package, available for specified devices and for large orders only.
   Chapter “Chip dimensions and bonding pad locations” shows exact pad locations for other delivery formats.

PINNING

SYMBOL	PIN	DESCRIPTION
V_{SS}	1	ground (0 V)
TEST	2	test output
OSC IN	3	oscillator input
OSC OUT	4	oscillator output
V_{DD}	5	positive supply voltage
M1	6	motor 1 output
M2	7	motor 2 output
RESET	8	reset input

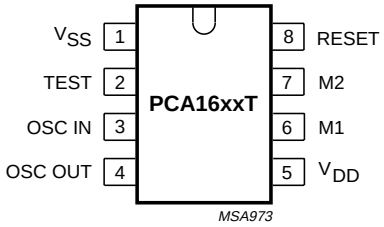


Fig.1 Pin configuration, PCA16xxT, (PMFP8).

FUNCTIONAL DESCRIPTION AND TESTING

Motor pulse

The motor pulse width (t_P) and the cycle times (t_T) are given in Chapter “Available types”.

Voltage level detector

The supply voltage is compared with the internal voltage reference V_{LIT} and V_{EOL} every minute. The first voltage level detection is carried out 30 ms after a RESET.

Lithium mode

If a lithium voltage is detected ($V_{DD} \geq V_{LIT}$), the circuit will operate in the lithium mode. The motor pulse will be produced with a 75% duty factor.

Silver-oxide mode

If the voltage level detected is between V_{LIT} and V_{EOL}, the circuit will operate in silver-oxide mode.

Battery end-of-life[1]

If the battery end-of-life is detected ($V_{DD} \leq V_{EOL}$), the motor pulse will be produced without chopping. To indicate this condition, bursts of 4 pulses are produced every 4 s.

Power-on reset

For correct operation of the Power-on reset the rise time of V_{DD} from 0 V to 2.1 V should be less than 0.1 ms.
All resettable flip-flops are reset. Additionally the polarity of the first motor pulse is positive: $V_{M1} - V_{M2} \geq 0$ V.

Customer testing

An output frequency of 32 Hz is provided at RESET (pin 8) to be used for exact frequency measurement. Every minute a jitter occurs as a result of time calibration, which occurs 90 to 150 ms after disconnecting the RESET from V_{DD}.

Connecting the RESET to V_{DD} stops the motor pulses leaving them in a HIGH impedance 3-state condition and a 32 Hz signal without jitter is produced at the TEST pin. A debounce circuit protects accidental stoppages due to mechanical shock to the watch (t_{DEB} = 14.7 to 123.2 ms).

Connecting RESET to V_{SS} activates Tests 1 and 2 and disables the time calibration.

Test 1, $V_{DD} > V_{EOL}$. Normal function takes place except the voltage detection cycle (t_V) is 125 ms and the cycle time t_{T1} is 31.25 ms. At pin TEST a minute signal is available at 8192 times its normal frequency.

Test 2[2], $V_{DD} < V_{EOL}$. The voltage detection cycle (t_V) is 31.25 ms and the motor pulse period (t_{T2}) = 31.25 ms.

Test and reset mode are terminated by disconnecting the RESET pin.

Test 3, $V_{DD} > 5.1$ V. Motor pulses with a time period of t_{T3} = 31.25 ms and n × 122 µs are produced to check the contents of the EEPROM. At pin TEST the motor pulse period signal (t_T) is available at 1024 times its normal frequency. The circuit returns to normal operation when V_{DD} < 2.5 V between two motor pulses.

(1) Only available for types with a 1 s motor pulse.

(2) Only applicable for types with the battery end-of-life detector.

Time calibration

Taking a normal quartz crystal with frequency 32768kHz, frequency deviation ($\Delta f/f$) of $\pm 15 \times 10^{-6}$ and C_L = 8.2 pF; the oscillator frequency is offset (by using non-symmetrical internal oscillator input and output capacitances of 10 pF and 15 pF) such that the frequency deviation is positive-only. This positive deviation can then be compensated for to maintain time-keeping accuracy.

Once the positive frequency deviation is measured, a corresponding number 'n' (see Table 1) is programmed into the device's EEPROM. This causes n pulses of frequency 8192 Hz to be inhibited every minute of operation, which achieves the required calibration.

The programming circuit is shown in Fig.2. The required number n is programmed into EEPROM by varying V_{DD} according to the steps shown in Fig.3, which are explained below:

1. The positive quartz frequency deviation ($\Delta f/f$) is measured, and the corresponding values of n are found according to Table 1.
2. V_{DD} is increased to 5.1 V allowing the contents of the EEPROM to be checked from the motor pulse period t_{T3} at nominal frequency.
3. V_{DD} is decreased to 2.5 V during a motor pulse to initialize a storing sequence.
4. The first V_{DD} pulse to 5.1 V erases the contents of EEPROM.
5. When the EEPROM is erased a logic 1 is at the TEST pin.
6. V_{DD} is increased to 5.1 V to read the data by pulsing V_{DD} n times to 4.5 V. After the n edge, V_{DD} is decreased to 2.5 V.
7. V_{DD} is increased to 5.1 V to store n bits in the EEPROM.
8. V_{DD} is decreased to 2.5 V to terminate the storing sequence and to return to operating mode.
9. V_{DD} is increased to 5.1 V to check writing from the motor pulse period t_{T3}.
10. V_{DD} is decreased to the operation voltage **between** two motor pulses to return to operating mode. (Decreasing V_{DD} during the motor pulse would restart the programming mode).

The time calibration can be reprogrammed up to 100 times.

Table 1 Quartz crystal frequency deviation, n and t_{T3}

FREQUENCY DEVIATION $\Delta f/f$ ($\times 10^{-6}$)	NUMBER OF PULSES (n)	t_{T3} (ms)
0[1]	0	31.250[2]
+2.03	1	31.372
+4.06	2	31.494
.	.	.
.	.	.
.	.	.
+127.89	63	38.936

Notes

1. Increments of 2.03×10^{-6}/step.
2. Increments of 122 μs/step.

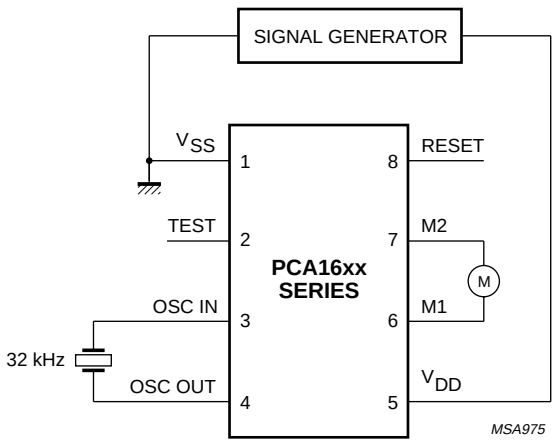


Fig.2 Circuit for programming the time calibration.

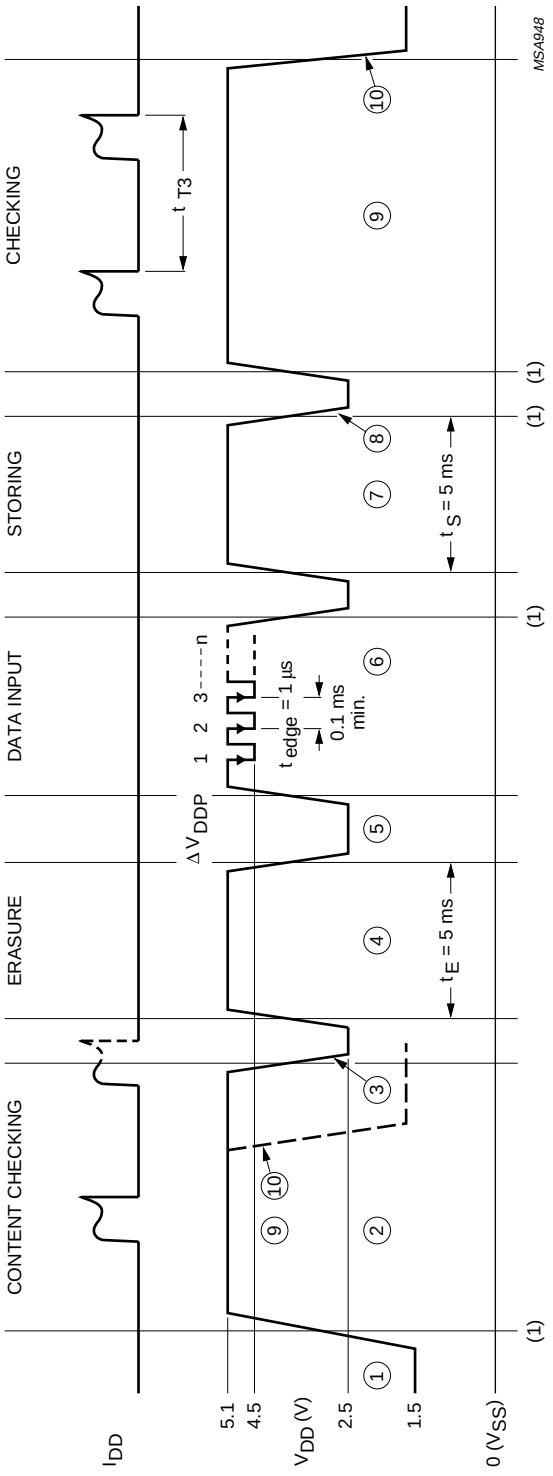


Fig.3 V_{DD} for programming.

(1) Rise and fall time should be greater than 400 µs/V for immediately correct checking.

AVAILABLE TYPES

Refer to Fig.4 and to Chapters “Ordering information” and “Functional description and testing”.

SHORT TYPE NUMBER	DELIVERY FORMAT(1)	PERIOD t_T (s)	SPECIFICATIONS				
			PULSE WIDTH t_P (ms)	DRIVE (%)	EEPROM	BATTERY EOL DETECTION	REMARKS
1601	U/10	1	7.8	100	yes	no	
1602	T	1	7.8	75	yes	no	
1603	U/7	20	7.8	100	yes	no	
1604	U/10	5	7.8	75	yes	no	
1605	U/7	5	4.8	75	yes	no	
1606	U/10	10	6.8	100	yes	no	
1607	U	5	5.8	100 75	yes	no	1.5 V and 2.1 V Lithium
1608	U	5	7.8	100 75	yes	no	1.5 V and 2.1 V Lithium
1611	U	1	6.8	75	yes	no	
1621	U/7	20	4.8	100	yes	no	
1622	U	1	4.8	100	yes	yes	
1623	U	20	4.8	75	yes	no	
1624	U	12	3.9	75 56	yes	no	1.5 V and 2.1 V Lithium
1625	U/7	5	5.8	75	yes	no	
1626	U	20	5.8	100	yes	no	
1627	U/7	20	5.8	100 75	yes	no	1.5 V and 2.1 V Lithium
1628	U	20	5.8	75	yes	no	
1629	U/7	5	6.8	75	yes	no	

Note

1. U = Chip in trays; U/7 = chip with bumps on tape; U/10 = chip on foil.
   T = SOT144-1.

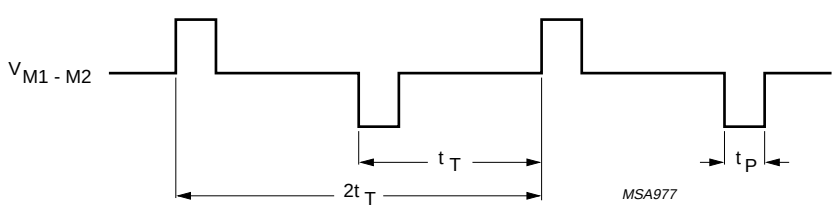


Fig.4 Motor output waveform (normal operation).

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{DD}	supply voltage	V_{SS} = 0 V; note 1	–1.8	+6	V
V_I	all input voltages		V_{SS}	V_{DD}	V
	output short-circuit duration		indefinite		
T_{amb}	operating ambient temperature		–10	+60	°C
T_{stg}	storage temperature		–30	+100	°C

Note

1. Connecting the battery with reversed polarity does not destroy the circuit, but in this condition a large current flows, which will rapidly discharge the battery.

HANDLING

Inputs and outputs are protected against electrostatic discharges in normal handling. However, to be totally safe, it is advisable to take handling precautions appropriate to handling MOS devices. Advice can be found in *"Data Handbook IC16, General, Handling MOS Devices"*.

CHARACTERISTICS

V_{DD} = 1.55 V; V_{SS} = 0 V; f_{osc} = 32.768 kHz; T_{amb} = 25 °C; crystal: R_S = 20 kΩ; C_1 = 2 to 3 fF; C_L = 8 to 10 pF; C_0 = 1 to 3 pF; unless otherwise specified.

Immunity against parasitic impedance = 20 MΩ from one pin to an adjacent pin.

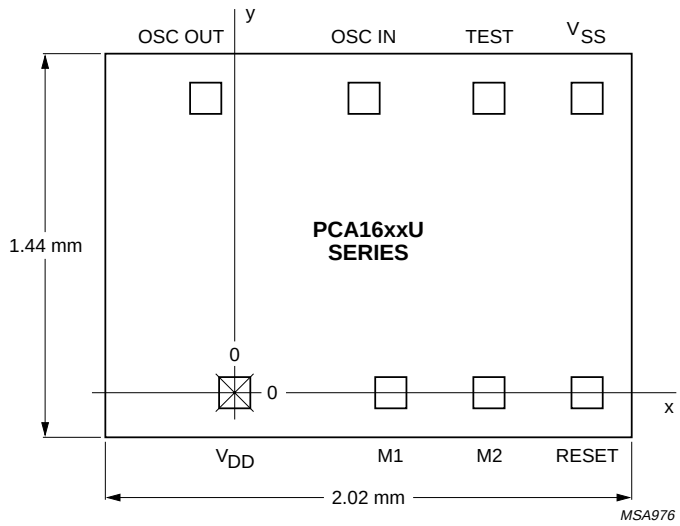
SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supply						
V_{DD}	supply voltage	T_{amb} = –10 to +60 °C	1.2	1.5	2.5	V
ΔV_{DD}	supply voltage variation	transient; V_{DD} = 1.2 to 2.5 V	–	–	0.25	V
V_{DDP}	supply voltage pulse	programming	5.0	5.1	5.2	V
ΔV_{DDP}	supply voltage pulse variation	programming	0.55	0.6	0.65	V
I_{DD1}	supply current	between motor pulses	–	170	260	nA
I_{DD2}	supply current	between motor pulses; V_{DD} = 2.1 V	–	190	300	nA
I_{DD3}	supply current	stop mode; pin 8 connected to V_{DD}	–	180	280	nA
I_{DD4}	supply current	stop mode; pin 8 connected to V_{DD}; V_{DD} = 2.1 V	–	220	360	nA
I_{DD5}	supply current	V_{DD} = 2.1 V; T_{amb} = –10 to +60 °C	–	–	600	nA

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Motor output						
V_{sat}	saturation voltage Σ (P + N)	R_L = 2 kΩ; T_{amb} = –10 to +60 °C	–	150	200	mV
R_{sc}	short-circuit resistance Σ (P + N)	$I_{transistor}$ < 1 mA	–	200	300	Ω
t_T	cycle time		note 1			
t_P	pulse width		note 2			
Oscillator						
$V_{OSC\ ST}$	starting voltage		1.2	–	–	V
g_m	transconductance	$V_{i(p-p)} \leq 50$ mV	6	15	–	µS
t_{osc}	start-up time		–	1	–	s
Δf/f	frequency stability	ΔV_{DD} = 100 mV	–	0.05×10^{-6}	0.3×10^{-6}	
C_i	input capacitance		8	10	12	pF
C_o	output capacitance		12	15	18	pF
Voltage level detector						
V_{LIT}	threshold voltage	lithium mode	1.65	1.80	1.95	V
V_{EOL}	threshold voltage	battery end-of-life	1.27	1.38	1.46	V
ΔV_{VLD}	hysteresis of threshold		–	10	–	mV
TC_{VLD}	temperature coefficient		–	–1	–	mV/K
t_V	voltage detection cycle		–	60	–	s
Reset input						
f_o	output frequency		–	32	–	Hz
ΔV_o	output voltage swing	R = 1 MΩ; C = 10 pF	1.4	–	–	V
t_{edge}	edge time	R = 1 MΩ; C = 10 pF	–	1	–	µs
I_{im}	peak input current	note 3	–	320	–	nA
$I_{i(av)}$	average input current		–	10	–	nA
Test mode						
	cycle time for motor pulses in:					
t_{T1}	test 1		–	125	–	ms
t_{T2}	test 2		–	31.25	–	ms
t_{T3}	test 3		see Chapter “Available types”			
t_{DEB}	debounce time	RESET = V_{DD}	14.7	–	123.2	ms
Battery end-of-life						
t_{EOL}	end-of-life sequence		–	4	–	s
t_{E1}	motor pulse width	see “Available types”	–	t_P	–	ms
t_{E2}	time between pulses		–	31.25	–	ms

Notes

1. Cycle time can be changed to one of the following values: 1, 5, 10, 12 or 20 s (see Chapter “Available types”).
2. Pulse width can be varied from 2 ms to 15.7 ms in steps of 1 ms (see Chapter “Available types”).
3. Duty factor is 1 : 32 and RESET = V_{DD} or V_{SS}.

CHIP DIMENSIONS AND BONDING PAD LOCATIONS



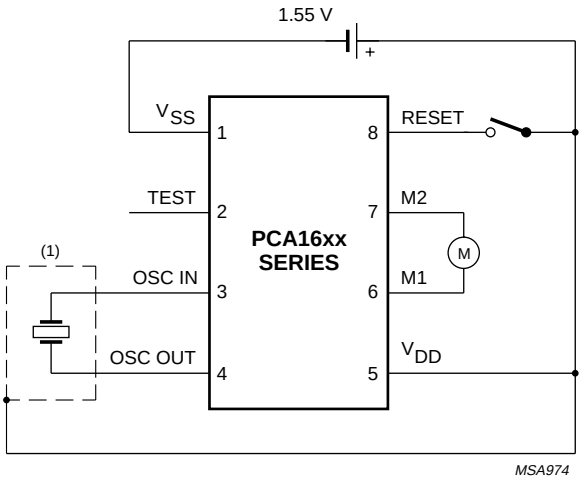
Chip area: 2.91 mm^2.
Bonding pad dimensions: 110 µm × 110 µm.
Chip thickness: 200 ±25 µm, with bumps: 270 ±25 µm.

Fig.5 Bonding pad locations, PCA16xxU series, 8 terminals.

Table 2 Bonding pad locations (dimensions in µm)
All x/y coordinates are referenced to the centre of pad (V_{DD}), see Fig.5.

PAD	x	y
V_{SS}	1290	1100
TEST	940	1100
OSC IN	481	1100
OSC OUT	–102	1100
V_{DD}	0	0
M1	578	0
M2	930	0
RESET	1290	0
chip corner (max. value)	–497.5	–170

APPLICATION INFORMATION

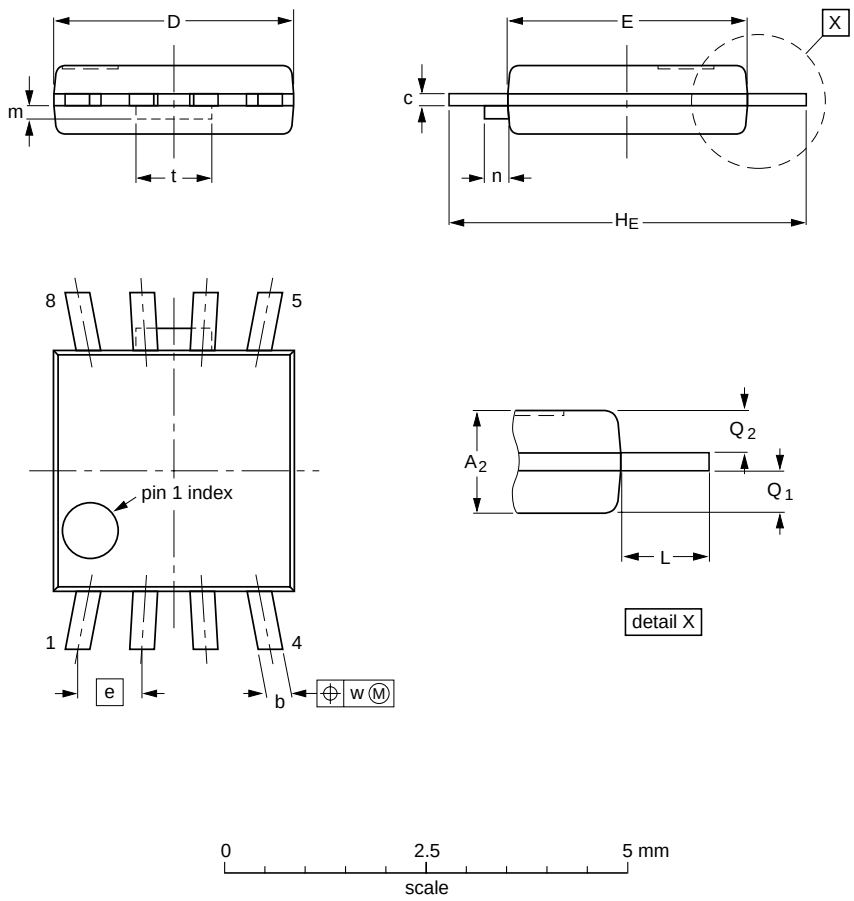


(1) Quartz crystal case should be connected to V_{DD}. Stray capacitance and leakage resistance from RESET, M1 or M2 to OSC IN should be less than 0.5 pF or larger than 20 MΩ.

Fig.6 Typical application circuit diagram.

PACKAGE OUTLINE

PMFP8: plastic micro flat package; 8 leads (straight) **SOT144-1**



DIMENSIONS (mm are the original dimensions)

UNIT	A_2	b	c	$D^{(1)}$	$E^{(1)}$	e	H_E	L	m max.	n max.	Q_1	Q_2	t	w
mm	0.90 0.70	0.40 0.25	0.19 0.12	3.1 2.9	3.1 2.9	0.80	4.6 4.4	0.75	0.26	0.3	0.40 0.30	0.40 0.30	0.95	0.1

Note

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT144-1						~~94-01-25~~ 95-01-24

SOLDERING

Introduction

There is no soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and surface mounted components are mixed on one printed-circuit board. However, wave soldering is not always suitable for surface mounted ICs, or for printed-circuits with high population densities. In these situations reflow soldering is often used.

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our *"IC Package Databook"* (order code 9398 652 90011).

Reflow soldering

Reflow soldering techniques are suitable for all SO packages.

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement.

Several techniques exist for reflowing; for example, thermal conduction by heated belt. Dwell times vary between 50 and 300 seconds depending on heating method. Typical reflow temperatures range from 215 to 250 °C.

Preheating is necessary to dry the paste and evaporate the binding agent. Preheating duration: 45 minutes at 45 °C.

Wave soldering

Wave soldering techniques can be used for all SO packages if the following conditions are observed:

- A double-wave (a turbulent wave with high upward pressure followed by a smooth laminar wave) soldering technique should be used.
- The longitudinal axis of the package footprint must be parallel to the solder flow.
- The package footprint must incorporate solder thieves at the downstream end.

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Maximum permissible solder temperature is 260 °C, and maximum duration of package immersion in solder is 10 seconds, if cooled to less than 150 °C within 6 seconds. Typical dwell time is 4 seconds at 250 °C.

A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

Repairing soldered joints

Fix the component by first soldering two diagonally-opposite end leads. Use only a low voltage soldering iron (less than 24 V) applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C. When using a dedicated tool, all other leads can be soldered in one operation within 2 to 5 seconds between 270 and 320 °C.

DEFINITIONS

Data sheet status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.

NOTES

NOTES

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